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THE EFFECT OF LENGTH AND TYPE OF
MATERIAL UPON LEARNING

DISSERTATION

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the degree of Doctor of Philosophy

by

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"

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The Effect of Length and Type of Material upon Learning.

I. Historical Summary.

The history of the present inquiry with the relation of the length of the series to the number of repetitions required for learning goes back to the experimental work of Ebbinghaus (6) in 1885. Before this time there had been no carefully controlled experimentation upon memory, but the work of Ebbinghaus stimulated investigation into a wide range of problems in this field. Ebbinghaus included among his own investigations research upon the problems of the relation between the length of series to be learned and the labor required for its learning.

Very few of those who have since conducted investigations of memory have worked extensively upon this problem. Moreover some have so deviated from the method of Ebbinghaus, namely the method of complete memorization or "Erlernungsmethode", that their results cannot be compared with his.

Ebbinghaus originated the use of nonsense syllables as material for experimental work. As he used it, the nonsense syllable consisted of either a vowel or diphthong placed between two consonants. The series were composed of nonsense syllables drawn by chance and were in length 7, 12, 16, 24 and 36 syllables each. In the learning of these series

Ebbinghaus followed a very definite procedure which was in brief:

1. Each separate series was read through from beginning to end without special emphasis upon any portion of the series.
2. The reading and recitation were done in time with a metronome which beat at the rate of 150 strokes a minute or $2\frac{1}{2}$ strokes a second.
3. Owing to the difficulty of maintaining equal stress upon all syllables, either the first, fourth and seventh, or the first, fifth and ninth syllables were slightly accented.
4. An interval of 15 seconds between series was allowed for the tabulation of results.
5. An effort was made to concentrate upon the work.
6. All mnemonic devices were avoided.
7. An endeavor was made to have the subject in as nearly as possible the same mental and physical state as the beginning of each test period.

Each test consisted in learning a certain number of series of a given length. A test, for example, might consist in learning two series of 36 nonsense syllables, or in learning nine series of 12 syllables.

The results which Ebbinghaus gives were derived from tests which were given as indicated in Table I. It is to be noted that in counting the number of repetitions an

attempt at reproduction was counted as a repetition. Upon hesitation in reproduction the rest of the series was read through to the end. In Table I the first errorless reproduction is counted in the averages for the total repetitions for each test, and deducted in the averages of the repetitions for each length of series.

TABLE I

Ebbinghaus

No. of tests	No. of series in each test	Syllables in the series	Average of total repetitions in each test	Average of repetitions for each length of series
		7		1
7	9	12	158	16.6
42	6	16	186	30.0
7	3	24	134	44.0
7	2	36	112	55.0

It is observed that there is an increase in the number of repetitions with an increase in the length of the series, and that the increase in the number of repetitions is relatively greater than the increase in the length of the series, e.g., doubling the length of the series more than doubles the number of repetitions.

In a later publication (5) in which Ebbinghaus summarizes further work upon the same problems, we find this statement: "Whereas I am able almost without exception to recite a series of 6 nonsense syllables without a mistake

after a single presentation, I can recite series of 12 syllables, read rapidly, only after some 14 to 16 repetitions, series of 16 only after 30, and series of 36 only after 55".

In 1894, Müller and Schumann (19) published the results of their research upon memory. Although they did no work upon the particular problem with which we are here concerned, their investigation had bearing upon further work through their refinement of the method of constructing a series of nonsense syllables. Whereas Ebbinghaus had chosen all syllables by chance, these investigators showed by experiment that a chance selection permitted combinations which facilitated the learning of a series. They determined that learning was aided.

1. If two or more syllables had the same beginning consonant.

2. If two syllables rhymed.

3. If two successive syllables contained the same vowel or diphthong.

4. If the beginning consonant of one syllable were the same as the end consonant of the succeeding syllable.

5. If two or more syllables made a word or phrase.

In making up a series, therefore, they avoided the conditions set forth above.

The work of Binet and Henri (3) upon school children published in 1894, showed the influence of Ebbinghaus.

They tested the immediate and delayed recall of series of nonsense syllables. The method of procedure differed from that of Ebbinghaus in that each series was presented a given number of times, whereupon the reproduction of as much as possible was required. A brief experiment of the same order was conducted upon adults.

Binet (2) also used somewhat the same method as Ebbinghaus in his testing of Diamandi, the calculator, for the learning of a series of digits of different lengths. In this case the total time required for learning was considered rather than the number of repetitions. The time was taken from the moment when the written sheet was placed before the subject until his written reproduction was completed. Table 2 represents the result of one experiment and shows in a marked degree the relatively much greater increase in time with increase in the length of the series.

TABLE 2

Binet

No. of digits.	Time required.
10	17 sec.
15	1 min. 15 sec.
20	2 min. 15 sec.
25	3 min.
30	4 min. 20 sec.
50	7 min.
100	25 min.
200	2 hr. 15 min.

The first actual repetition of Ebbinghaus' experiment was made by Radossowljewitsch and Meumann (24) in 1903. The

experiment was conducted with Meumann as the subject. The syllables were arranged upon a kymograph in such a way that by rotating the drum the syllable would pass before a slit in a screen. The circumference of the drum was 49.5 cm. The distance between the syllables varied with the length of the series. In a twelve syllable series the distance between the middle points of two successive syllables was 4 cm. There was a blank space at the end of the series of about 9 cm. The rate of rotation varied with the length of the series (and with the distance between the syllables). The drum was set to rotate in 9 seconds for 8 syllables, 10 seconds for 12 syllables, and 12 seconds for 16 syllables. Since the syllables were at varying distances (depending upon the length of the series) the change of rate tended to equalize the period of exposure. We have been unable to determine the rates which were used for the 18, 24 and 36 syllable series. In any case, there was an appreciable difference in length of exposure of the individual syllables between series of different lengths.

Meumann learned five series of 8 and 12 syllables, and two series of 16, 18, 24 and 36 syllables. The average of repetitions required are given in Table 3.

TABLE 3

Radosowljewitsch and Meumann

No of syllables	No. of repititions
8	5.2
12	10.4
16	17.
18	21.5
24	30
36	32.5

These results have been given by Meumann (16, p. 276) as illustrative of economy in learning with increase in the length of the series. An examination of the results shows, however, that such is not the case. In all but one instance, if we double the length of the series we more than double the number of repetitions. The single exception is found in the series of 36 syllables which requires less than double the number of repetitions that are required for 18 syllables. Certainly these results as a whole cannot be taken as contradictory to the findings of Ebbinghaus.

In 1911, Henmon (10) reported some research which he had done in an attempt to repeat the experiment of Ebbinghaus. The series were composed of 10, 12, 14, 16, 18, 20, 24 and 30 syllables. The material was presented visually in the Ranschburg apparatus. With reference to the rate of exposure, Henmon gives merely the statement, "Series were presented at a rate which permitted the exposure of each syllable for 1-1/4 seconds". Two subjects took part in the

experiment, which was conducted by the method of complete memorization. The results which he gave (Table 4) represent the average number of repetitions required for learning, based on 8 experiments in the case of Subject H and 3 experiments in the case of Subject C.

TABLE 4

Henmon

No. of syllables	No. of Repetitions	
	Subject H.	Subject C.
10	6.9	12.7
12	8.1	14.0
14	8.3	15.3
16	8.6	15.0
18	10.6	16.3
20	13.6	19.0
24	12.9	16.0
30	20.0	25.7

Henmon concludes: "The results of the experiment diverge widely from those of Ebbinghaus and Binet^{and} are closely in accord with those of Meumann and Radossowljewitsch. There is a relative decrease in the number of repetitions as the number of syllables increases. Particularly noteworthy is the fact that the number of repetitions for the series from 10 to 18 is practically constant. The results are even more striking than those of Meumann in showing the relative economy with the longer series".

In 1914, Lyon (14) reported an experiment upon the relation of length of material to the time taken for

learning. The materials used were nonsense syllables, digits, prose and poetry.

With respect to the method of procedure Lyon makes the following statements: "In the following experiments only two methods were used. I have designated them as (1) the "continuous" method, and (2) the "once per-day" method. In the former the subject is allowed to memorize the material en masse, i.e., in one sitting; in the latter the subject memorizes the material by reading it once per day and once only, until memorized".

The materials first used were nonsense syllables and poetry. With these the experiment continued for 14-1/2 months. Digits and prose were then substituted and the entire performance repeated. The manner of conducting the experiment was as follows: "On May 1, 1908, I memorized 8 nonsense syllables taking my time by the watch!"..... "With nonsense syllables two days were allowed to elapse after each 'finishing' with the 'continuous' method and seven days with the 'once-per-day' method.

A consultation of one of his figures showed that Lyon had read the syllables and the digits at the rate of two per second. No timing apparatus was mentioned other than his watch. The results were as follows:

TABLE 5

Lyon

No. of syllables	Time required	No. of digits	Time required
8	1/4 min.	8	1/12 min.
12	6 min.	12	1/4 min.
16	9 min.	16	2 min.
24	16 min.	24	5 min.
32	28 min.	32	10 min.
48	43 min.	48	18 min.
72	138 min.	72	24 min.
		104	56 min.
		200	154 min.

The results, in so far as the time required for learning may be compared with the number of repetitions conform more closely to those of Ebbinghaus than those of Meumann.

We may mention here the work of Kjerstad (12) on the relation between the length of series and the number of repetitions, which work was incidental to his main investigation of the learning curves of memory.

Series of paired nonsense syllables and serial nonsense syllables were used. The material was presented visually by means of a hand operated memory drum which brought each syllable or pair of syllables before an aperture in a screen. The period of exposure was for three seconds. In the paired material each pair was presented for this length of time, in the serial material each single syllable.

In Table 6, in which he compares his results with those of Ebbinghaus and Meumann, Kjerstad gives the results

of only two subjects in the serial nonsense material, and four in the paired nonsense material "because they were the only ones in whom we were certain that the practice effect had been eliminated before these results were taken".

TABLE 6

Kjerstad

No. of syllables	No. of Repetitions	
	Serial Syllables	Paired Syllables
12	4.8	6.5
18	6.1	7.6
24		7.7
36		8.7

In conclusion, he says: "It is evident that our results point conclusively to an opposite conclusion to that of Ebbinghaus. With increase in the length of material there is only a very slight increase in the number of repetitions required.

We question whether a comparison of paired syllables with serial material is permissible since the two methods employ quite different types of organization of material. The serial material is treated as a unit within which associations are set up not only between the first syllable and the second, the second and third, and so on, but also between the first and third, the first and fourth and so on. In the case of paired syllables the two syllables constitute a single unit. The whole consists of a certain

number of these units, and the reactor is not required to memorize the series as a unit. In the case of paired syllables the addition of one pair to the whole complicates the problem far less than would the addition of two syllables to the unpaired serial material.

Robinson and Heron (26) have recently conducted an experiment upon the results of variations in length of memorized material upon (1) its susceptibility to retro-active inhibition, (2) the form of curve of memorizing, (3) the difficulty of learning it, (4) the amount of retention after a certain interval.

The experiment was made upon ten subjects. The materials employed were lists of nonsense syllables of 6, 9, 12, 15 and 18 syllables in length. The material was presented visually by means of a hand-operated memory drum. "The time for the single exposure of a syllable was 2 seconds. The experimenter was made aware of these intervals by means of a mercury cup metronome in circuit with a head-phone".

The method of learning differed from that of Ebbinghaus. Robinson and Heron employed what they term the "anticipation" method. To quote, "The entire list was presented once and, after that, the subject, upon being presented with a given syllable, attempted to pronounce the three letters of the next syllable in the list before that syllable appeared. He was not permitted to anticipate aloud more of the list than that one syllable following the one

which was exposed. Each list was presented until the subject had successfully anticipated during a single presentation all but the first of its syllables".

The method differs in several respects from that of Ebbinghaus. By the method of anticipation the bond between each syllable and its succeeding syllable tends to be strengthened. A failure to call up a syllable upon the presentation of the preceding syllable serves to fix the position of the 'wanted' syllable. Also, the direction of association, if it may be so designated, is not fixed in the serial presentation. Frequently the subject recalls the last syllable, then the next to the last, and the second from the last. By the use of the method of anticipation there is a tendency, it seems to us, to establish a certain direction of association.

Before the experiment proper, each subject learned one list of 12 syllables a day for a period of six days, and then relearned the same list after an interval of 15 minutes.

The experiment contained three cycles. "That is" says Robinson, "each of our subjects was tested three times under each experimental condition. This gave us a total of 30 values apiece for each of these conditions". In no case was a subject tested under more than one condition on a single day.

The results are given in Table 7 in terms of the average number of repetitions per syllable of lists of different length.

TABLE 7

Robinson and Heron

Length of List	6 syl.	9 syl.	12 syl.	15 syl.	18 syl.
Cycle I	. 0.67	. 0.90	. 1.11	. 1.20	. 1.21
Cycle II	. 0.62	. 0.82	. 0.85	. 0.98	. 0.99
Cycle III	. 0.45	. 0.77	. 0.79	. 0.80	. 0.73
Averages of 3 Cycles.	0.58	0.83	0.92	0.99	0.98

In conclusion we quote, "Two out of three cycles of this experiment agree in showing an increasing number of repetitions per syllable with increasing length. In all cycles, this increase grows less as the length further increased. In one cycle, the third, there is an actual decrease in repetitions per syllable as the longest length is reached. These findings agree with the majority of those obtained with nonsense syllables in showing a sudden increase in the number of repetitions per syllable with early increases in the length of material, and less pronounced increase in repetitions per syllable or, perhaps even a decrease, with later increases in the length of material.

The results as we have seen have been not altogether harmonious with the original findings of Ebbinghaus, but are by no means in conflict with his general conclusion. An inspection of the procedure will show, however, that many have deviated far from Ebbinghaus in method. There is still room for extensive experimentation upon the problems of the relation between the length of the series and the number of repetitions required in learning it.

II. Method of Experimentation.

The period of experimentation extended from Dec. 1, 1922 to April 15, 1923. Five reactors were used who served for one hour a day on two days a week. The same hour and the same days were maintained for each reactor throughout the period. All the hours were in the morning.

Of the reactors three (H. S. and W.) were undergraduate men at the Johns Hopkins University, two (R. and D.) were graduate women at the University. H had had the most practice, having served in preliminary experiments of the same order two and three days a week for four months. S had had three months practice, W one month, R three weeks and D none.

The material to be tested was of five types: Nonsense syllables, monosyllabic words, three-place numbers, and consonant groups of two sorts. This material was presented in series of six different lengths: 4, 8, 12, 16, 20 and 24. It would have been desirable to have included series of greater length but we were unable to do so within the limits of our investigation.

The material was presented visually by means of the new exposure apparatus devised by Dunlap and Pullen. In this apparatus a drum 4 inches in diameter and 3.5 inches long moved a strip of paper behind the exposure aperture in an efficient manner. The strip was pressed against the drum by

two rollers one above and one below the aperture, so that the paper moved accurately a half inch at a time, and permitted the use of strips of any length. The exposure aperture is adjustable in length and width, for this experiment having been fixed at 1/4 inch wide and 3 inches long. The aperture was 1/8 inch from the drum.

The drum was moved by an ingenious combination of work wheel, coiled spring, magnetic release and winding motor, by which the successive advances of the drum were accurate and extremely rapid so that ~~the~~ each word or other material remain^{ed} in view almost the full time of the exposure interval, then snapped quickly out as the next came in.

The magnetic release was actuated by a contact clock, set for this experiment with contacts ^{Per} one _^ second.

The material of the experiment was typewritten on adding machine paper, in capitals for the words, syllables and consonant groups. The aperture and exposed material were illuminated by an electric light in a reflector so as to shield the reactor's eyes from the direct rays. The reactor sat so that the eyes were in line with the exposed material, and at a distance of two feet.

In the actual preparation of the material certain rules were observed. In the case of nonsense syllables, we made a list of all the possible combinations of a vowel placed between the consonants. From this list we discarded

all the words, all nonsense syllables that obviously sounded like words and those which could be transformed into words by adding a final e. This left a list of about 900. The choice of the proper nonsense syllables is unfortunately an individual matter. Whereas we made use of 900 nonsense syllables, Lyon (14 p. 162) maintains that there are approximately 90 nonsense syllables which may be considered "fairly good".

From our revised list we drew out nonsense syllables by chance to form the series used. In case the syllable did not conform to the following rules it was thrown back.

1. No syllables contained a vowel or consonant which had appeared in the immediately preceding syllables.

2. No two syllables which together formed a word were used successively.

From a complete list of monosyllabic words composed of a vowel placed between two consonants we made up lists according to the following rules:

1. No word contained a vowel or consonant which had appeared in the immediately preceding word.

2. Proper names were excluded.

3. No two words which together made another word were used in succession.

In the case of numbers, the lists were made by drawing by chance from a complete list of three Place numbers.

All numbers conformed to these rules:

1. In no number was 0 employed.
2. No digit occurred twice in the same number.
3. The same digit did not occur in two successive numbers.
4. Sequences such as 345, 456, 987 and 654 were avoided.
5. Sequences such as 246, 468, 248, 357 and 579 were avoided.

The lists of consonants were of two sorts, those drawn from all the consonants and those drawn from only the first nine consonants of the alphabet.

In the formation of lists of the first sort (all consonants) we first made a list of all the possible combinations of consonants in groups of threes. From this list the groups (three consonants each) were drawn by chance, subject to the following rules:

1. No consonant occurred twice in the same group.
2. No group contained a consonant which had appeared in the preceding group.
3. The alphabetical order was avoided as for example F G H.

In the lists of the second sort, namely those drawn from the first consonants of the alphabet we followed exactly the order which we used in the numbers. Whereas we used, let us say, 135 in a number list we used the cor-

responding consonants B D G in the consonant list, but the order of the consonant groups was determined by chance.

The reactor was provided with a pad and sharp pencil which were placed on the writing shelf of the chair.

All the reactors at the opening of the experiment understood the general operation of the apparatus. The following instructions were given at the opening trial:

"I shall present a series of four numbers. At the close of the series write down all that you can recall in the proper order leaving spaces for those which you do not recall. Write the numbers promptly and do not go back over them.

The series will be repeated until you have learned all the numbers in their order. You will write at the close of each presentation".

All reactors were asked to refrain from the use of lip, tongue and throat movements. They were also asked to avoid mnemonic devices.

At the close of the learning of a series the experimenter frequently called for a report of any peculiarities in the series itself or in the learning of the series. Care was taken to avoid giving the reactor suggestions as to methods or peculiarities which had not occurred to him.

In every case through the period of investigation the reactor was informed concerning the length of the series and the type of material before the presentation of a series.

The signal "Ready" was given approximately one half second before the appearance of the first number of syllable. At the conclusion of each presentation the reactor began to write at once.

It seemed wise to require a reproduction of the material after each presentation. We found in a preliminary investigation that it was very difficult to determine the number of presentations that should be given for series of various lengths and to persons of varying capacities before a reproduction should be required. Since reproductions are undoubtedly an aid to learning, their number should be considered among the factors in the learning.

We preferred the method of reproduction by writing inasmuch as we had employed a visual method of learning. It seemed to us that a vocal reproduction led to an exaggeration of the tendency to use lip, throat and tongue movements in learning.

The reactor was allowed an interval of five minutes between the completion of one series and the presentation of the next. During this time the experimenter engaged the reactor in casual conversation. The reactor never worked for longer than one hour except in cases where a single series required more than that amount of time. The report of the reactor upon the peculiarities of the series and of the learning was given at the close of the hour.

As we have stated, four of the reactors were

practised observers. There were five types of material. In order that no type should be given the advantage in learning the material was presented to the five reactors in the following order.

MATERIAL PRESENTED

Reactor	Material Presented.										
H	.	Numbers	.	9 Cons.	.	All Cons.	.	Nons.	.	Words.	.
S	.	9 Cons.	.	Numbers	.	Nons.	.	Words	.	All Cons.	.
W	.	All Cons.	.	9 Cons.	.	Words	.	Nons.	.	Numbers	.
R	.	Nons.	.	Words	.	All Cons.	.	All	.	9 Cons.	.
	.		.		.		.	Cons..	.		.
D	.	Words	.	Nons.	.		.		.		.

The series were presented in order from the shortest to the longest. The period of time required for the completion of all the material varied with the capacities of the reactors.

Three of the reactors (H. S. and W.) who learned more rapidly than the other two were given in addition to the preceding tests, the complete set of series in numbers and nine consonants, but in the reverse order, namely, from the longest series to the shortest.

RESULTS

We shall consider first the effect of the length of series upon learning, and secondly the effect of the type of material.

The results are given in Tables 1-7, and are represented by the graphs in Figures 1-7.

We shall be interested in observing whether there is uniformity in the results of the various reactors, whether the increase in repetitions with the increase in length of series is gradual or rapid, and whether the increase in repetitions is relatively greater than the increase in the length of the series.

An inspection of Figure 1 (Words) shows a great deal of uniformity in the rate of increase of repetitions for the four practical reactors. Reactor D, who was unpracticed showed a very different type of curve. With the practiced reactors the increase in the number of repetitions with increase in the length of series was very gradual throughout.

We find that the increase in the number of repetitions is relatively greater than the increase in the length of the series. It is not, however, so much greater as Ebbinghaus found with nonsense syllable.

In Figure 2 (Nonsense Syllables) we find great uniformity in the rate of increase in repetitions for the four practiced reactors. Reactor D again gives a wholly different type of curve. The increase in the number of repetitions is very gradual for nonsense syllables as for words.

The increase in the number of repetitions we find to be relatively greater than the increase in the length of the series in the case of all practical reactors.

In Figure 3 (Numbers) we find less uniformity in the performances of the four practiced reactors. Reactor D was used for the shorter lengths of series but was unable to learn the series beyond 16 within the hour. Because of the difficulty with the series and her great nervousness she was not retained for the rest of the experiment. We have not recorded her performance in this test since she was unable to complete it. With respect to the rate of increase we find a much greater increase in work from series of 4 numbers to those of 8 than in the case of nonsense syllables or words.

In the case of the three most practiced reactors there was a slight relative decrease in the number of repetitions with increase in the length of the series. The fourth showed a relative increase.

In Figure 4 (Nine Consonants) we find two reactors requiring an increasing number of repetitions for series of 20 consonant groups above those of 16. The other two reactors show an absolute decrease in the number of repetitions required for 20 from than required for 16. It was found from the introspective accounts of S and W, who show the decrease, that there was at a certain stage increasing association of consonants with words. Reactor W showed this in a marked degree and was cautioned anew by the experimenter to avoid any mnemonic devices. He denied, however, that he consciously tried to associate the con-

sonants with words.

In this figure, a comparison of the repetitions required for the various lengths, shows that for two reactors there is throughout a relative increase in the number of repetitions with increase in length, while for two reactors there is a relative decrease in the number of repetitions required in series above 12 in length.

In the case of series made from all the consonants, Figure 5, we find greater uniformity among the reactors. There is the usual relative increase in the number of repetitions required for a series of 8 over one of 4. The increase in repetitions, both relative and absolute, is very pronounced from 8 to 12. All reactors are uniform in showing a relative decrease in the number of repetitions for all lengths above 12 as compared with a series of 12. As in the case of the series composed of nine consonants, the factor of associating consonants with words came in to influence the number of repetitions.

We tested our reactors, H, W. and S. upon series composed of nine consonants and numbers to learn the form of the curve when the series were presented in the order from the longest to the shortest. A comparison of Figure 6 (Numbers) shows that the type of curve is, in general, much the same for each reactor in the two tests. It is to be noted that when the series are learned by taking the

shortest first, that there was no absolute increase in repetitions required for 24 numbers above that for 20, but when the order is reversed, there is both an absolute and relative increase in the number of repetitions required for 24 numbers above that required for 20. This is important, of course, in connection with the question of the influence of practice effects.

A comparison of Figure 7 (Nine Consonants) with Figure 4 (Nine Consonants) shows a marked similarity. The greatest point of difference lies in the fewer repetitions required for learning a series of 12 consonant groups in the second order. Here too, it is clear that there is a relative increase in the number of repetitions with increase in the length of material.

We may say then that there is more uniformity in the results with the use of words and nonsense syllables than in the results with consonants and numbers. The rate of increase is gradual in all cases except that of consonants chosen from the first nine of the alphabet.

We find that for words and nonsense syllables there is a slight relative increase in the number of repetitions with increase in length. In the case of numbers and nine consonants when learned in order from shortest series to longest, there is evidence of slight relative decrease in repetitions for the longest series. This decrease is not

found when the reverse order of learning is employed. In the case of consonants chosen from all the alphabet there is in general a relative decrease with length in all series above 12 as compared with a series of 12.

With our reactors, in work with increasing length or decreasing length of series, the relative increase is very slight as compared with Ebbinghaus' results.

With respect to the effect of the type of material upon learning we find enough variations in the curves for the different types of material to warrant our testing each type separately.

Words, as one might expect are the easiest. Nonsense syllables are next in difficulty, then numbers, all-consonant groups and finally nine-consonant groups.

The introspective reports of the various reactors throw some light upon the learning of the material. Words had numerous associations and were learned as units. Nonsense syllables were also learned as units, and were thought of as they sounded rather than as they appeared when visually presented. Numbers were seldom complete units but were composed of two units since the number was thought of most frequently as 3-47 rather than 347 or 3-4-7. Consonant groups were composed of three units. The reactors reported that each letter had to be thought of as a unit. Whenever there was association with a word - as was not infrequent learning was greatly facilitated. Nine-consonant material

was more difficult than material chosen from all the consonants, owing to the fact that within the same series the same consonant was used in different but similar combinations.

The factors which enter into every experiment with memory are numerous. The factor of 'anticipatory' inhibition is not unimportant. When a reactor has learned one series, this very fact may cause inhibition in the learning of another series. Ideally an interval of at least one day should come between the learning of any two series. Even so, it would be impossible to estimate the effect of 'anticipatory' inhibition. Since we employed only immediate recall, the factor of retroactive inhibition was unimportant.

The matter of the effect of practice is the hardest of all to control, nor has it always been taken into account by the various investigators. Unless the experimenter used only subjects in which the practice effects were no longer operative, there existed a practice effect in the learning of the series. In case the series was learned in the order of increasing length, the longer series showed the effects of practice, and required a relatively less number of repetitions than they should have in comparison with the shorter series.

Ebbinghaus went through preliminary experiments of the same nature as the tests until from the results he

judged the time of increasing still had passed. Then, too, he took the results of a considerable number of tests. Radossowljewitsch does not state what practice Meumann had had before taking the test. The results were taken from a comparatively few tests. Henmon based his results upon a number of experiments with each subject. He does not mention whether the order of presentation is varied. Since Lyon does not mention the factor of practice, we do not know what the effects of practice may have been in his case. Kjerstad judged that the practice effect had been eliminated before his results were taken. Robinson and Heron put their subjects through a series of preliminary tests. They also varied the order of presentation of the various lengths of series.

In our own investigation the four reactors had preliminary training. Unfortunately, the period of our experimentation and the amount of material did not permit us to put each reactor through three or more cycles of material, each cycle representing a different order of presentation.

An unpracticed reactor in learning a series in order of increasing length would undoubtedly learn the longer series in a shorter time because of practice. In comparing the curves for the two orders of presentation, the curves, in case the reactor showed no practice effects,

should be practically the same. The fact that in the case of numbers there was in the increasing length of series practically no increase in repetitions from 20 to 24, but that in decreasing order of series there was a relatively greater number of repetitions for 24 than for 20 leads us to believe that we had not entirely eliminated practice effects. Since our reactors had been practiced for a long period we hold it advisable to proceed on the assumption that the point is never reached where there is cessation of practice effects and to present the material in cycles so that several orders of presentation are represented.

III. Methods of Learning Disclosed by Reports.

The reports upon learning disclosed peculiarities in the learning which might otherwise have been overlooked. Although the series was presented as a whole, the first syllable was learned and then the last syllable before the others. Though there was no conscious effort to learn the series in parts, by learning first one section then another there was a tendency to localize any presented syllable as belonging to the first third, last third and middle. Frequently the reactors had learned completely the first third and last third and were hazy upon the middle. This tendency seemed to grow up from the fact that the first syllable and the last syllable are first to be learned, and so forth, the reactor then working from these two points.

The fact that the observers wrote the reproduction may have helped (undoubtedly did help) in the localization of a syllable as belonging to a certain "part". The mere fact that gaps were left unfilled called attention to the fact that certain "parts" were learned, others were hazy.

We found it practically impossible to keep the reactors from making small tongue movements. One reactor claimed that he was unable to learn anything without "saying it to himself". All reported a strong tendency toward throat and tongue movements.

IV. Conclusions.

We find that, in general, with increase in the length of the series there is a relative increase in the number of repetitions required.

The relative increase in repetitions with increasing length is, however, much less than found by Ebbinghaus.

TABLE 1

Words.

Reactor	Length of Series							
	4	8	12	16	20	24		
H	1	2	2	7	7	12		
S	1	2	5	6	7	11		
W	1	4	5	5	5	8		
R	1	2	3	4	5	6		
D	1	6	7	18	11	14		

TABLE 2

Nonsense.

Reactor	Length of Series							
	4	8	12	16	20	24		
H	1	4	4	7	7	11		
S	1	4	5	10	13	13		
W	2	4	7	8	11	14		
R	2	4	4	9	10	19		
D	2	14	24	17	19	25		

TABLE 3

Numbers.

Reactor	Length of Series							
	4	8	12	16	20	24		
H	2	8	8	7	10	8		
S	2	8	14	16	22	17		
W	4	13	11	14	15	16		
R	2	7	12	18	25	25		

TABLE 4

Nine Consonants.

Reactor		Length of Series							
		4	8	12	16	20	24		
H	.	2	8	15	19	38	43	.	.
S	.	3	8	30	25	22	27	.	.
W	.	6	12	21	26	14	14	.	.
R	.	4	12	22	29	43	58	.	.

TABLE 5

All Consonants.

Reactor		Length of Series							
		4	8	12	16	20	24		
H	.	2	6	12	9	12	13	.	.
S	.	3	6	9	12	17	16	.	.
W	.	3	5	14	14	14	9	.	.
R	.	3	7	18	16	16		.	.

TABLE 6

Numbers

Reactor		Length of Series							
		4	8	12	16	20	24		
H	.	1	2	6	7	7	11	.	.
S	.	2	7	7	14	15	23	.	.
W	.	2	5	7	9	14	20	.	.

TABLE 7

Nine Consonants

Reactor		Length of Series							
		4	8	12	16	20	24		
H	.	2	6	11	14	21	30	.	.
S	.	1	4	7	15	18	24	.	.
W	.	3	5	6	19	20	14	.	.

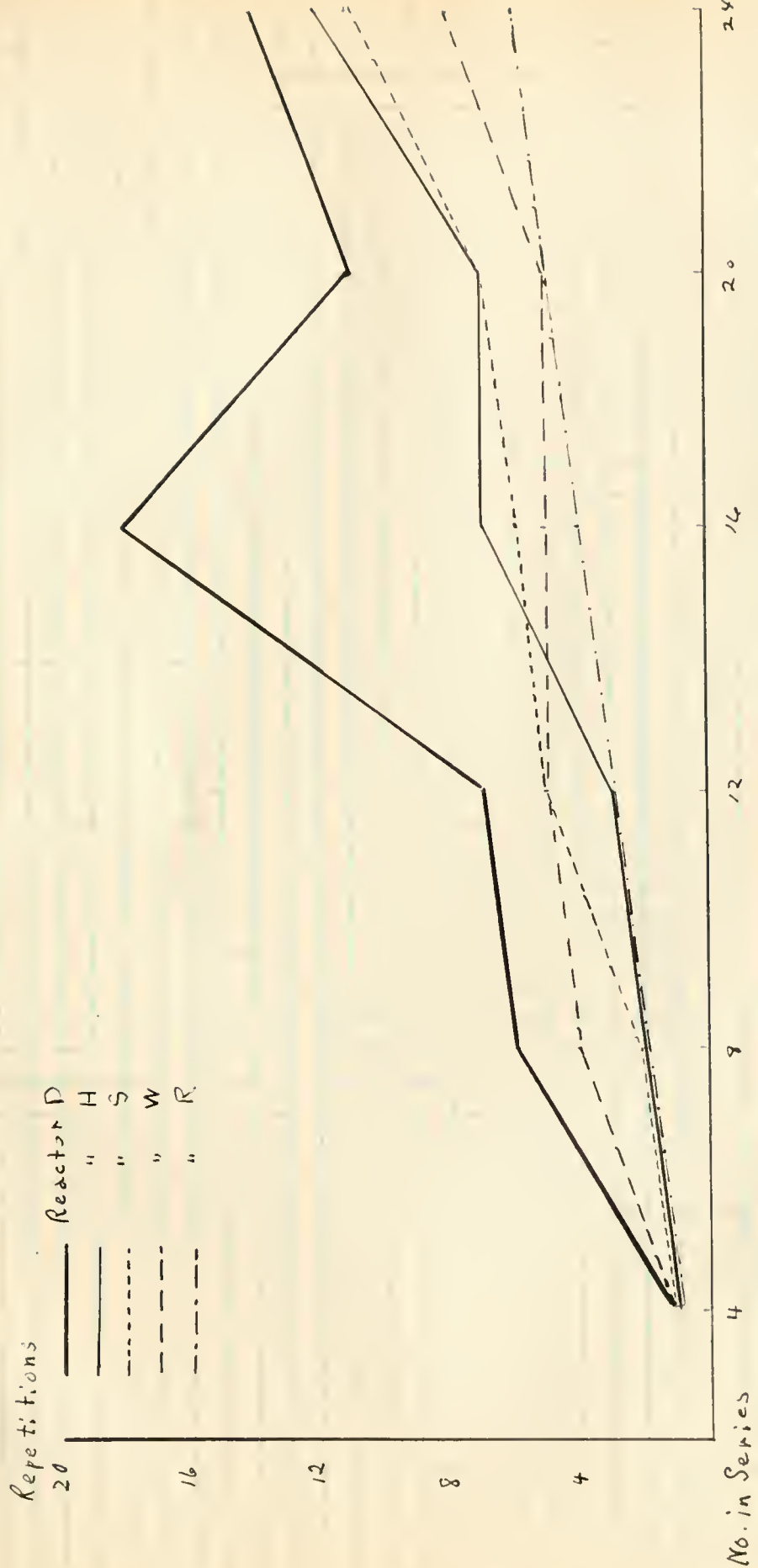


Figure 1
Words

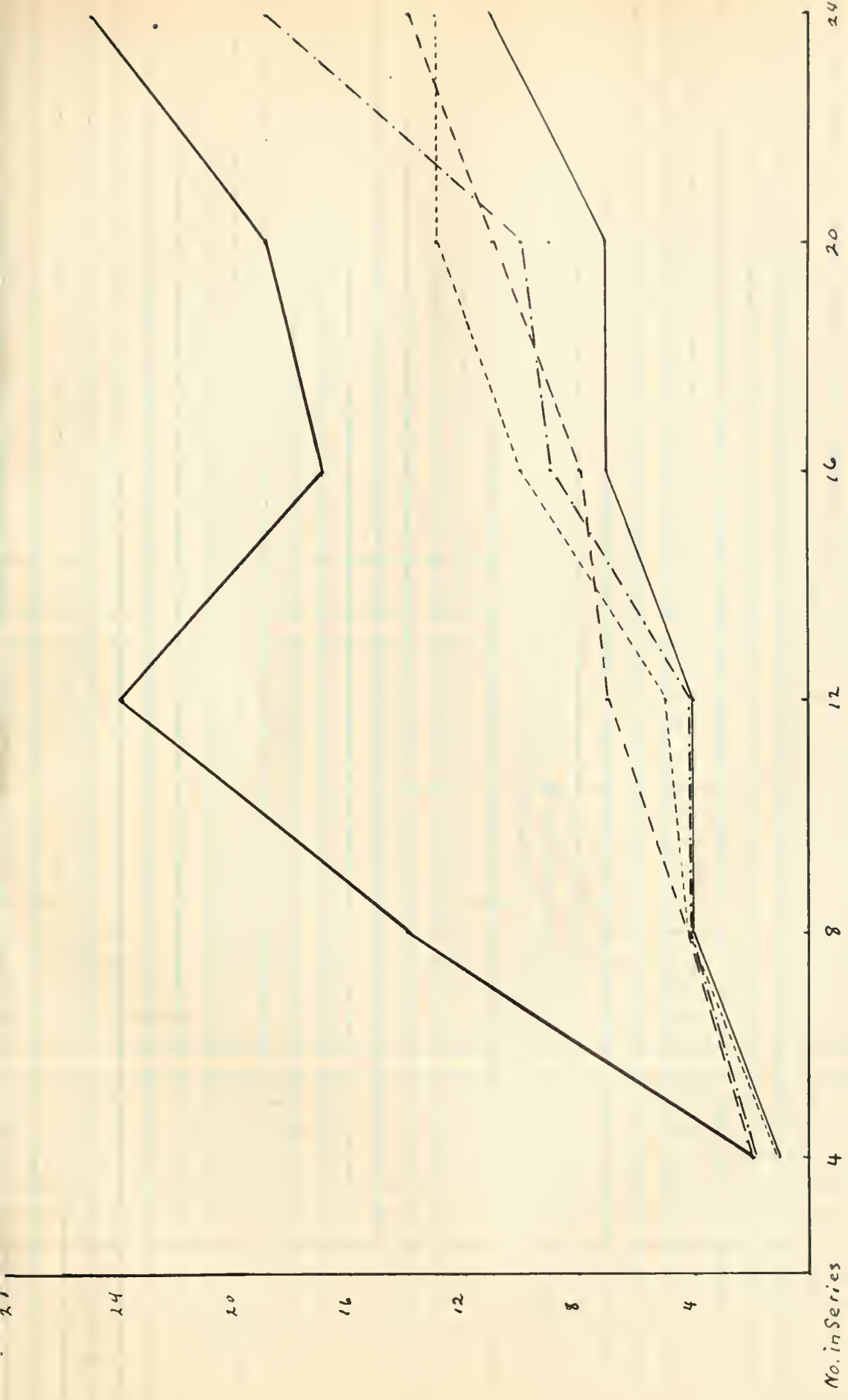


Figure 2
Nonsense.

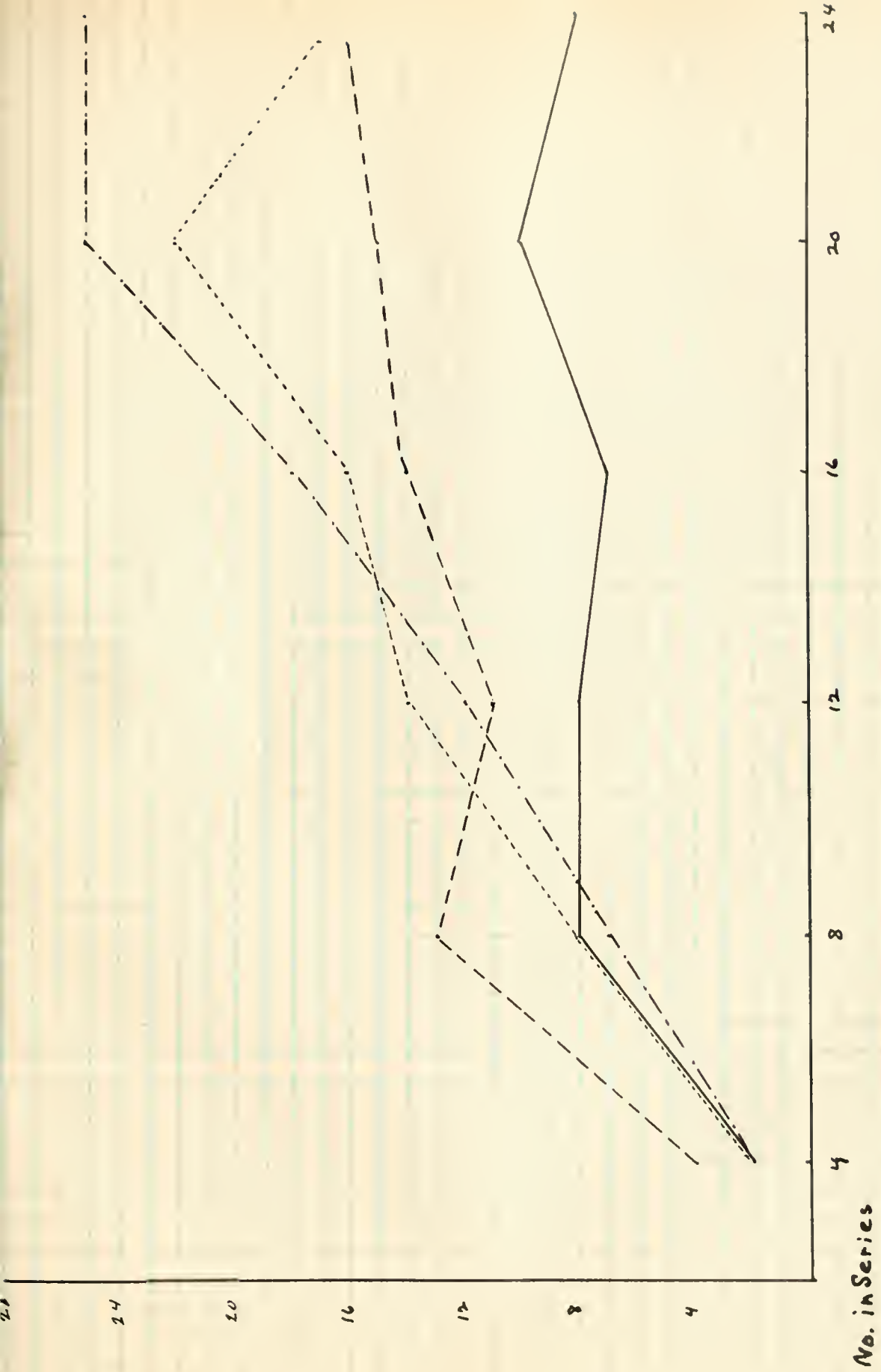
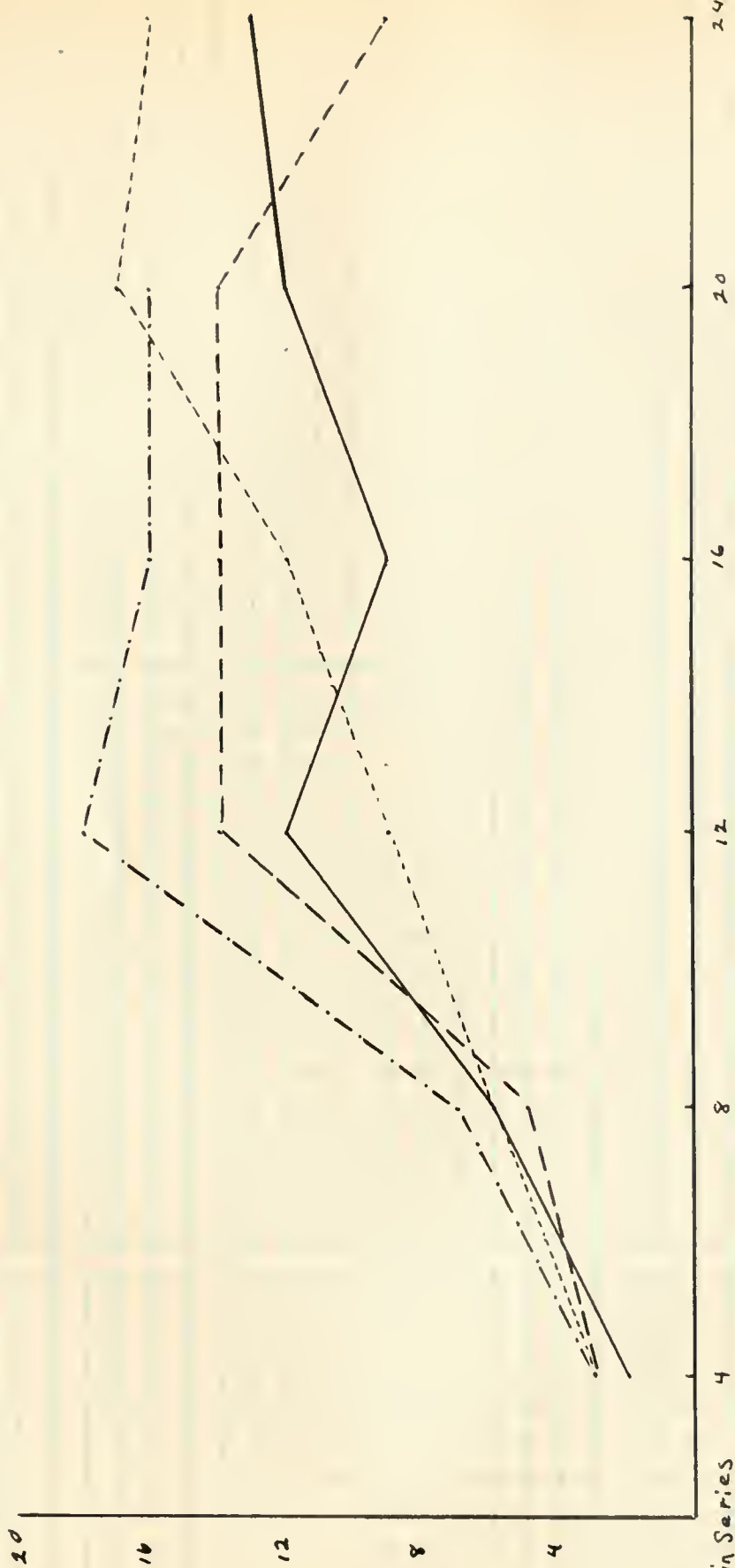


Figure 3
Numbers



Figure 4
Nine Consonants

Repetitions



No. in Series

Figure 5

All Consonants

Repetitions

24

20

16

12

8

4

No. in Series

4

8

12

16

20

24

Figure 6
Numbers



Figure 7
Nine Consonants

SET I.

Series of 4.

Words	Nonsense	Number	9 Cons.	All Cons.
L I P	K U H	4 9 6	F L H	B M F
C A N	B O D	3 5 2	D G C	G T D
S O T	Z A G	7 1 9	T B L	S C V
R U N	S E P	8 2 4	K C F	T D X

Series of 8.

B I T	C I H	6 3 4	H D F	V C M
M A R	P O F	7 1 2	J B C	T L S
S E T	G A C	9 4 8	L F K	R H P
R I D	P U M	6 7 1	H J B	N L B
F O P	K A J	4 2 9	F C L	S G X
G A S	H I B	8 3 6	K D H	J M V
T O N	B E X	1 5 7	B G J	P F Z
H U B	V O G	4 9 3	F L D	G B J

Series of 12.

M O P	L E N	3 2 8	D C K	T V B
C U T	Z U R	6 1 5	H B G	S L C
W A S	W O F	9 7 2	L J C	M B K
R I M	T E G	8 5 4	K G F	X N T
S O N	R U C	1 2 7	B C J	R B V
T A P	D A Z	3 9 6	P L H	K J F
G U M	J U V	4 1 2	F B C	H I K
P O D	L O R	7 8 5	J K G	L B D
T I N	M E L	6 4 9	H F L	V M J
B U S	J I C	5 7 3	G I D	B K G
M I T	G A K	8 2 9	K C L	M D R
F A R	N E P	7 4 6	J F H	P B J

Series of 16.

B I N	X A D	8 3 5	K D G	C L M
P A D	C E F	4 1 9	F B L	B R K
T U G	H I G	3 6 7	D H J	V F G
L I T	V O B	4 5 1	F G B	X D H
H O G	L E P	9 7 3	L J D	K G S
W I N	T A S	1 4 8	B F K	P M T

Series of 16 (con.)

Words	Nonsense	Numbers	9 Cons.	All Cons.
B U T	M U J	7 2 9	J C L	L J Q
G E M	R E F	3 1 6	D B H	Z N S
T A G	B O Y	9 4 5	L F G	J P R
R E D	S U Z	8 3 2	K D C	T M C
H U M	N O H	6 1 7	H B J	D B P
N O T	T E B	5 9 2	G L C	S V F
F U R	P A M	6 7 4	H J F	P J X
P I N	X E L	3 8 1	D K B	C I R
B E G	J O F	4 7 9	F J L	B L P
C O T	V U T	1 2 5	B C G	M B C

Series of 20.

G U N	M E D	6 4 1	H F B	S L B
B A R	Z A S	3 8 5	D K G	C V D
F O G	T E M	2 9 7	C L J	B T J
R I B	S I B	4 3 8	F D K	P R L
H A S	K A L	9 5 2	L G C	S M X
C U T	J E P	1 7 6	B J H	R C K
G I N	X U S	5 8 3	G K D	V T G
H O P	V E D	6 4 2	H F C	M C J
F I T	S A B	3 9 7	D I J	X L D
M O B	D O X	1 5 4	B G F	B J V
P A D	P E F	2 3 9	C D L	D M S
R O T	R A L	4 8 1	F K B	F R B
H A M	S I G	9 2 7	L C J	S B K
T I P	B O P	3 5 6	D G H	H C R
H A G	C I F	7 1 8	J B K	N D T
S O D	D E J	4 6 3	F H D	P H M
M E T	Z O G	8 7 2	K J C	K B S
B U N	T U J	5 9 1	G L B	C X L
L A D	L E B	7 3 2	J K C	V D B
S I T	H U K	4 5 9	F G L	T C K

Series of 24.

W I T	V O S	8 5 3	K G D	B L X
B E D	X I F	7 9 2	J L C	G D V
S I P	M A N	1 4 6	B F H	P C K
B A N	J U P	7 5 2	J G C	M B R
M E T	V O M	8 1 4	K B F	T F S
D O G	F E G	3 7 5	D J G	V D C
F I N	G O F	8 4 9	K F L	L H R

Series of 24 (con.)

Words	Nonsense	Numbers	9 Cons.	All Cons.
B A T	T I B	1 7 2	B J C	J N Q
C O G	N U Z	5 9 4	G L F	K G P
T A M	B O F	7 3 6	J D H	S Z M
P I T	J E D	9 8 2	L K C	P R G
D O N	K I B	1 6 5	B H G	S K V
W I G	V E L	3 9 2	D L C	B P L
P A L	Z I P	4 6 7	F H J	X J K
B U M	B O L	2 1 8	C B K	M C T
K I N	S E F	9 4 1	L F B	Q F G
S O B	W A B	5 6 8	G H K	S J N
T E N	K U H	7 2 3	J C D	H D R
L O P	T E F	5 4 9	F D L	L X S
W A G	N A D	8 6 1	K H B	T L K
S O P	P U T	4 9 2	F L C	V P Z
R I G	N I V	6 3 5	H D G	D Q S
P U N	T O B	2 4 9	C F L	J M R
G O T	K E L	7 1 6	J B H	X V B

SET II.

Series of 4.

Numbers	9 Cons.
4 1 6	F B H
3 2 9	D C L
1 5 6	B G H
2 8 4	C K F

Series of 8.

3 1 5	D B G
6 9 4	H L F
8 2 1	K C B
5 6 3	G H D
2 1 7	C B J
9 4 2	L F C
6 5 3	H G D
1 2 9	B C L

Series of 12

Number	9 Cons.
7 3 4	J D F
5 2 6	G B H
8 9 1	K L B
2 7 4	C J F
9 2 5	L C G
6 3 8	H D K
1 4 2	J F C
3 6 5	D H G
2 8 7	C K J
4 1 6	F C H
5 3 8	G D K
1 4 7	B F J

Series of 16.

Number	9 Cons.
1 7 9	B J L
3 8 6	D K H
4 2 1	F C B
7 6 3	J H D
5 2 4	G C F
8 1 6	K B H
9 2 3	L C D
7 1 4	J B F
2 5 8	C G K
3 9 1	D L B
6 8 5	H K G
1 9 7	B L J
2 3 8	C D K
9 5 4	L G F
6 7 2	H J C
5 3 8	G D K

Series of 20.

Numbers	9 Cons.
9 2 6	L C H
4 3 1	F D B
5 8 9	G K L
6 2 3	H C D
4 7 8	F J K
2 5 9	C G L
3 7 1	D J B
2 8 5	C K G
1 4 9	B F L
6 3 7	H D J
1 4 5	B F G
8 2 6	K B H
4 9 7	F L J
3 5 8	D G K
1 7 4	B J F
9 3 2	L D C
5 6 4	G H F
3 7 9	P J L
4 5 2	F G C
9 3 1	L D B

Series of 24.

Number	9 Cons.
6 5 1	H G B
4 3 9	F D L
8 7 5	K L G
9 6 1	L H B
8 5 7	K C J
2 4 3	C F D
5 1 8	G B K
7 2 6	J C H
5 9 3	G L D
6 4 7	H F J
8 5 9	K G L
1 3 4	B D F
7 2 5	J C G
8 1 3	K B D
5 6 9	G H L
8 7 4	K J F
9 2 1	L C B
6 7 5	H J G
4 9 1	F L B
3 8 7	D K J
9 1 5	L B G
7 8 4	J K F
1 3 9	B D L
6 2 7	H C J

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V I T A

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